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PINE MANAGEMENT INFLUENCES THE SOUTHERN WATER RESOURCE

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Abstract.--Activities required to meet the anticipated demand for southern pine products in the next 25 years may temporarily impair water quality and significantly reduce streamflow and groundwater recharge. However, management practices can probably ameliorate such changes without seriously interfering with wood production. The information needed to establish realistic water quality standards for southern forests is not available.

Additional keywords: Water yield, streamflow, water quality, watershed management, interception, site preparation, loblolly pine.

Foresters have generally been aware of the relationships between forests and water resources, but only recently have such interests become more than abstract reflections. Water is now becoming a key consideration, second only to wood production. Undoubtedly, this concern will intensify. I'd like to examine how management of the southern forest resource can affect water yield and distribution, sediment production, and water quality.

WATER YIELDS

In the South about 70 million acres of pine sites are covered with unwanted hardwoods (Anderson 1974). Converting 20 million acres of such hardwoods to pine and planting an additional 10 million acres of poorly stocked lands were recently listed as priority needs in The South's Third Forest (Southern Forest Resource Analysis Committee 1969). As these lands are converted to pine, a reduction in water yield can be anticipated. Recent studies at the Coweeta Hydrologic Laboratory have demonstrated that in the high rainfall belt of the southern Appalachians, conversion from mature mixed hardwoods to white pine (*Pinus strobus* L.) reduced annual streamflow by 8 area inches only 15 years after the pine were planted (Swank and Douglass 1974). Even greater reductions are expected as the trees develop.

In another study the net loss to interception by 10-, 20-, and 30-year-old loblolly (*Pinus taeda* L.) averaged about 19 percent of the annual rainfall; the interception loss from mature mixed hardwoods was estimated at 11 percent (Swank, Goebel, and Helvey 1972). Thus, replacing unwanted hardwoods with loblolly pine over much of its range will increase the annual interception loss by at least 4 inches, an amount equivalent to 20 to 25 percent of annual streamflow. The water lost by converting each acre of hardwoods to pine would equal the annual water requirements of one person. These figures may be conservative. An unpublished study in north Mississippi measured interception by

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loblolly pines planted at a 5- by 5-foot spacing. From measurements taken during the eighth and ninth years after planting, it was estimated that one-fourth of the 53-inch average annual rainfall would never reach the soil surface. Although loblolly will not be planted at such close spacing, similar early crown closures and foliage mass can be expected because of increasing emphasis on full stocking. Further, these studies did not consider the greater transpiration by loblolly than by hardwoods or other vegetation (Swank and Douglass 1974). Losses, of course, would be greater where pine is established on open land or poorly stocked hardwood areas.

In terms of water quantity alone, reduced water yields because of pine conversion would not create a widespread problem. There is plenty of water in the South. Streamflow over most of the area exceeds 15 inches. The Coastal Plain, comprising 10 percent of the continental United States, contains 40 percent of the country's fresh groundwater—and groundwater is the only true water reserve. However, there will be local shortages due to distributions of surface and ground waters, people, and water-using industries. In a recent survey, 29 percent of the southern municipal watershed managers listed seasonal distribution of flow and 21 percent listed water yield as problems (Dissmeyer, Corbett, and Swank, in press).

Competition for the allocation of rainfall between trees and man will appear first in areas dependent on streamflow or shallow water tables for their water supplies. Where water is pumped from confined aquifers—those whose outcrops or intake areas are remote from the pumping site—the relationship is more obscure. The few studies available indicate that shortages in such locations are due to the rate at which water can move through the aquifer and not to insufficient recharge or depletion of the aquifer itself. Here, too, shortages can be anticipated in fast-growing areas, and storage and use of surface water is usually the only alternative.

What can the forester do to alleviate these problems? For one thing, by regulating tree populations over a wide range he can influence water yield and distribution considerably without seriously reducing timber production (Williston 1967). Thus, in favorable soil-geologic situations, lower tree densitites and frequent cuttings can increase groundwater recharge where and when it is needed. Interception losses can be reduced 1 area inch for every 20-square-foot reduction in basal area of pole-size loblolly pine (Rogerson 1967), and thinnings result in temporarily higher reserves of soil water at the start of the recharge season. Where tree populations have a minor influence on water yields because soils are poorly drained, high densitites are desirable for flood reduction; low densities are best in situations where water demands dictate the need for surface storage. The distribution of age classes on a catchment also can be planned to optimize water production.

DISTRIBUTION OF FLOWS

Overland flow occurs on forested lands only with the most intense rains; most stormflows reach channels through subsurface routes (Lull and Reinhart 1972). How much of the rainfall is rejected and becomes stormflow depends primiarily on soil characteristics. In north Mississippi, outcrops of permeable Coastal Plain soils planted with loblolly pine can accept and store the entire winter's rainfall. Further, the time lag between winter precipitation entering the soil surface and the excess moving past the 30- to 35-foot

depth on its way to the water table and a local stream appears to be a very desirable 4 to 6 months. Similar forests on soils with drainage restrictions at shallow depths will reject up to 25 percent of the annual rainfall. Little of this flow runs over slopes. However, current studies of such situations in north Mississippi indicate water delivery to ephemeral channels is about as rapid through the soil as over the surface. Thus, as is evident from these two extremes, it is impossible to predict how a forest will affect water distribution without having soil and geologic information. To illustrate: average annual stormflows from eight small catchments of loblolly pine ranged from 0.1 to over 16 percent of average annual rainfall. This range represented differences of about 8 area inches of surface water yield, and differences in a wet year—say, 70 inches of rainfall—could approach 18 inches. These differences could be predicted rather well from the proportion of a catchment having soils with poor internal drainage and from annual rainfall data (Ursic and Duffy 1972).

SEDIMENT PRODUCTION

Planting southern pines on actively eroding, abandoned fields can in about 15 years reduce sediment production[2/] to amounts not much higher than normal erosion from the original, undisturbed natural forests (Ursic and Dendy 1965). On eight small, pine-covered headwater catchments in north Mississippi, sediment production averaged 13 pounds per acre-inch of stormflow, and most of this minute amount was produced from ephemeral channels created during prior agricultural use (Ursic and Duffy 1972). Sediment production from these 3- to 7-acre catchments could be satisfactorily estimated directly from annual stormflow. However, when the predictive relationships were applied to a similar area of 88 acres (a reasonably sized compartment for a clearcut and planting operation), water yields fell into line, but sediment production per acre of watershed was more than 13 times higher than expected (Tennessee Valley Authority 1962). This increase is explained as erosion of the sand channels on the larger area. Therefore, when water quality standards are established, it will be essential to differentiate between sediment delivered from slopes to channels and channel erosion per se.

Although pine plantations can minimize sediment production, forest management practices can create erosion problems. Harvesting and regenerating pine disturbs the soil and the protective forest floor and increases the potential for sediment production. Thinning causes only minor disturbances, but clearcutting and skidding with articulated, rubber-tired skidders may disturb up to 20 percent of a logged tract (Dickerson 1968), and mechanical site preparation may bare entire areas.

A recent study at the Forest Hydrology Laboratory measured soil movement and stormflows from trails created by uphill skidding on various soils, slopes, and slope lengths (B. P. Dickerson, "Stormflows and erosion after tree-length

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2/ In this paper, sediment production is defined as particulate matter reaching a channel; soil movement, as soil moving to a lower slope position. This distinction is important because available empirical methods of estimating erosion were developed from plot data and represent soil movement and not sediment production. If soil does not get into a channel, it is not pollution.

skidding on Coastal Plain soils," presented at ASAE 1974 Winter Meeting, Dec. 9-13, Chicago, Ill.). First-year soil movement averaged 0.84 ton per acre of skid trail. However, if skidding disturbed 20 percent of the area, soil movement from an entire logged area would be only 0.17 ton per acre per year. Again, this is soil movement and not necessarily sediment production. With proper layout of skid trails and with such obvious precautions as not crossing drainages or channels and leaving filter strips along channels, only a small part of the soil movement need actually reach a channel. Dickerson's study was on abused and poorly stocked, but not severely eroded, lands. An important unresolved question is what happens after harvesting lands with a lower recovery potential--specifically, pine plantations established to arrest erosion.

In any study of skidding damage, a variable difficult to assess is the skidder operator. Those I have observed apparently consider difficult terrain a challenge. I am convinced that disturbances from wheel tracks could be largely avoided without any significant loss in production. Soil moisture conditions are, of course, another important variable, and most damage could be prevented with some commonsense restrictions. Moehring and Rawls (1970) reported that soil physical properties were not significantly changed by logging traffic under dry conditions. On moist, medium-textured soils, Hatchell et al. (1970) recommend a minimum number of primary trails and remedial soil treatment after logging; on dry, porous soils, they recommend maximum dispersion of trails with no more than one or two trips per trail.

Intensive mechanical site preparation of southern hill lands presents the most serious erosion problem. Obvious abuses have occurred, and some restrictions will probably follow. For lands left essentially bare, bedding on contour to provide storage for overland flow and soil movement may be a solution. One large wood-using industry is bedding steep slopes in north Mississippi. Another ameliorating practice may be the establishment of a temporary vegetative cover, preferably of winter grasses and other vegetation which would minimize competition to new seedlings and provide food for wildlife.

Other techniques leave most of the debris on the soil surface, and the debris can trap much of the soil movement. For such techniques, closer attention to details can help alleviate the threat. For example, the simple expedient of running a 35-ton tree-crusher up and down slopes, rather than on contour, creates about 0.5 area inch of retention storage, thus potentially keeping up to 63 tons per acre of moving soil on site.

Currently, the land manager has no valid means of assessing the effects of site preparation on sediment production. There is urgent need to determine sediment yields for widely used methods and to develop practical alternatives where necessary.

How much sediment production should be allowed from forested lands? The Soil Conservation Service has set tolerable soil losses from crop lands at 3 tons or more per acre per year for the hilly sections of the southern Coastal Plains. This loss will not reduce the productivity of the land--i.e., soil-forming processes approximate erosional losses. Thus, losses from agricultural lands where stormflows average 5 area inches would be almost 100 times greater than typical losses from undisturbed pine forests. And, in reality, sediment production from agricultural lands is often higher (Ursic and Dendy 1965).

It is reasonable to expect that acceptable sediment production from forest lands should be lower than that from farm lands. However, once losses from forest lands have been defined, I believe it untenable to expect foresters to operate under more stringent restrictions than farmers, as a recent report suggests (Environmental Protection Agency 1973). Further, I feel consideration should be given to the fact that the southern pinery is oriented to a planting and clearcutting operation with pulpwood rotations of 18 to 35 years. Temporary increases in sediment production corresponding to these intervals might be allowable. On a catchment basis, only 1/18th to 1/35th of the area need be disturbed in any given year.

WATER QUALITY

Although the South is a water-rich area, surface supplies from forested headwaters are generally inadequate to maintain acceptable levels of water quality because of downstream loading (Douglass 1974). Forty percent of the southern municipal watershed managers recently identified water quality as their primary problem (Dissmeyer, Corbett, and Swank, in press).

Public Law 92-500 has set interim goals of "best practical technology" by 1977 and "best available technology" by 1983 for control of water pollution. A final objective of "zero discharge" of pollutants by 1985 is a goal, not a requirement. The application of existing knowledge on the hydrologic impact of forest practices is probably sufficient to meet the "best practical" goal. However, it will require more than the compilation of existing data to adequately define the "best available technology" by 1983. The identification of pollution sources and causes, the definition of practical alternatives, and the development of predictive capability are sorely needed.

Realistic quality standards for water destined for specific downstream uses must be established, and suitable management practices must be defined to meet pollution objectives. I urge each of you to exercise your influence to help obtain the necessary data and to make the standards as realistic as possible in your State. It seems quite possible that the present lack of data for southern conditions could result in unwarranted restrictions.

Although sediment is the primary pollutant of concern to southern forest managers, chemical water quality is also important. The need to establish base levels for mineral and organic constituents in waters from forested watersheds was recognized in two recent USDA Task Force Reports (Southern Region Agricultural Experiment Stations and U. S. Department of Agriculture 1974a, 1974b). Until we have this basic information for forest situations as influenced by soils, vegetation, and geology, it will be difficult to establish valid environmental standards and to evaluate the effects of forest practices on chemical water quality.

Information on the impact of forest land practices on water chemistry is generally lacking. In one northeastern situation, clearcutting without removing products and applying herbicides for 3 years to prevent vegetative recovery increased the concentrations of most ions studied; nitrate concentrations increased above the permissible level for drinking water (Likens et al. 1970). However, this treatment was applied to determine increases in water yield and is atypical. Experiments at the Coweeta Hydrologic Laboratory have not shown an accelerated loss of ions to streams after clearcutting (Johnson and Swank 1973). Unpublished

data obtained from five small, undisturbed catchments of loblolly pine, planted to arrest erosion in north Mississippi, showed that the annual inputs from rainfall and dry fallout of NO_3-N, NH_4-N, PO_4-P, Ca, and K actually exceeded the losses as dissolved constituents in intermittent stormflows (J. D. Schreiber, P. D. Duffy, and D. C. McClurkin, "Nutrient losses from five southern pine watersheds," presented at ASA Annual Meeting, Nov. 10-15, 1974, Chicago, Ill.). Rainfall was an important source of NO_3-N and NH_4-N to the pine cover. However, additional nutrients can be carried by particulate matter, and this phase needs to be defined. The effects of the rapid loss of the forest floor following deadening of depleted upland hardwoods (Ursic 1970) or clearcutting loblolly pine (Dickerson 1972) also need to be quantified in terms of stormflows, sediment production, and water chemistry.

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